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Cortical Control of Neural Prostheses

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Work Preformed During the Reporting Period

In this reporting period, we continued to record spike data from our previously implanted monkeys as well as three newly implanted ones. These animals were implanted with either micro-wire arrays consisting of Teflon-coated stainless steel wires (50 microns in diameter) arranged in two linear arrays of eight wires each (spaced two hundred microns apart), or polyamide-coated tungsten wires of the same diameter arranged in two linear arrays each consisting of eleven electrodes. The stainless steel electrode arrays were purchased from NB Labs and the tungsten arrays were made in our laboratory. Three Michigan electrodes were also used. In total, three surgeries were performed during this quarter, one on the second hemisphere of Monkey G and two on the initial hemisphere of Monkey I and Monkey H.

Monkey F, who had bilateral electrode arrays implanted in the two previous quarters continued to have single unit activity present throughout this reporting period. Noteworthy is the appearance of new units even late into this time period. This animal has subsequently been perfused, although activity was still present over 250 days out from the initial surgery.

The second hemisphere of Monkey G was implanted at the beginning of this quarter. During this surgery, an electrode was inserted into the medullary pyramids to provide an antidromic stimulus. As discussed in our previous reports, this was felt to be a means not only to optimize the depth of implantation of the electrode arrays, but also to determine unit stability. Some difficulty was met during the implantation of this device, causing the animal to be under anesthesia for an extended period of time, and led to a significant morbidity in this animal. This technique was re-addressed in preparation for our next surgery.

As the technique for placement of the depth electrode was refined, we returned to this technique at the time of our next surgery. Monkey I received three NB electrode arrays after implantation of the antidromic depth electrodes. Although antidromic responses were not found, more cellular activity was recorded on the NB wire arrays than in previous attempts. This has maximized at thirty-five units present on twelve of the electrodes.

Similar results were found at the time of our next attempt, on Monkey H, although this time we were able to elicit an improved antidromic response. The antidromic responses were clear on the one array placed entirely in the motor cortex. Presently, there is activity on up to thirty electrodes, while discriminating over fifty units. Our current impression is that the improved results are probably related to better protection of the cortical surface before and after surgery.

There are multiple groups working on the analysis of this data. Our general thrust has been towards the use of neural networks and the use of the population vector approach to help derive a neural trajectory from this activity. Using a self-organizing feature map and training it with all but one of the training runs from that day (for blinded testing data), an accuracy (neural prediction of the correct target) of approximately 76% can be obtained. This can further be improved by disregarding inconsistent data sets. Other groups are looking into the effect of synchrony and perturbation in order to improve the accuracy of our ultimate model.

Using a software client which can access the recorded cortical data in real-time from the Plexon corporation server, we have been able to derive real-time population vectors. Although our program is still in its infancy, the firing rates of the units are acquired, calculations performed, and a neural trajectory is thereby determined with a temporal resolution of 20 ms. This information can then be sent over the serial port to our robot arm. Currently our accuracy with this system is limited, with efforts being directed at improving our ability to derive 3-dimensional movement.

One of the objectives in our current study is to assess our ability to discriminate unit activity over a period of time. This is important for estimating how frequently the neural prostheses will need to be re-calibrated to achieve a certain performance. It may be possible to use multiunit activity, signals that cannot be resolved to single units, to extract arm trajectory information. This type of activity as well as the stability of isolated single units in time will be assessed for their usefulness as a control signal. One goal we have is to compare the daily waveform recordings over weeks to months and make channel-specific estimates as to the "identity" of the recorded neural population. We have developed a method using a principle component analysis to do this and we are beginning to answer these concerns to assess the longevity this technology.

Work anticipated for the Next Reporting Period

As the technique for placement of the antidromic electrode has been refined, we plan on returning to this at least one more time. The question as to whether or not this aids in electrode placement in a meaningful way is still a matter of controversy. We plan by the next report to have implanted the second hemisphere of the two monkeys discussed above. Our data analysis will continue primarily using neural networks and population vectors in order to extract directional information from the cortical signal. Improvements to our real-time system are in the process of being added. Finally, we will continue be looking into the stability question in order to establish criteria for using a prosthesis over the long haul.